Transport model study of the baryon-rich QGP in HIC

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- A multi-phase transport (AMPT) model
- Mapping QCD phase diagram
- Anisotropic flow
- Density fluctuation and final-state scattering
- Charm suppression
- Double phi peak

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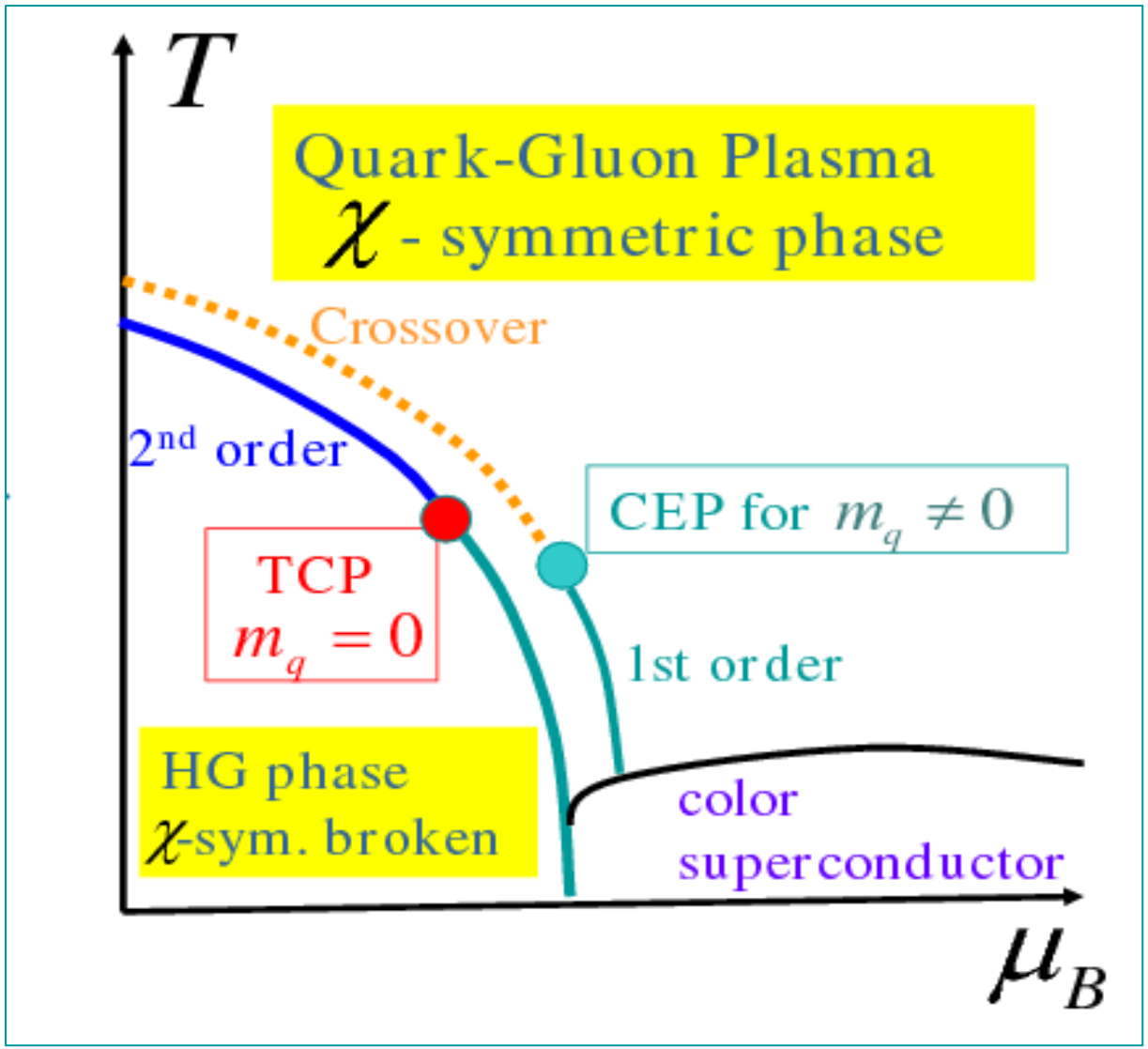
Supported by National Science Foundation and The Welch Foundation

QCD phase diagram

K. Redlich@QM2006



A multiphase transport (AMPT) model

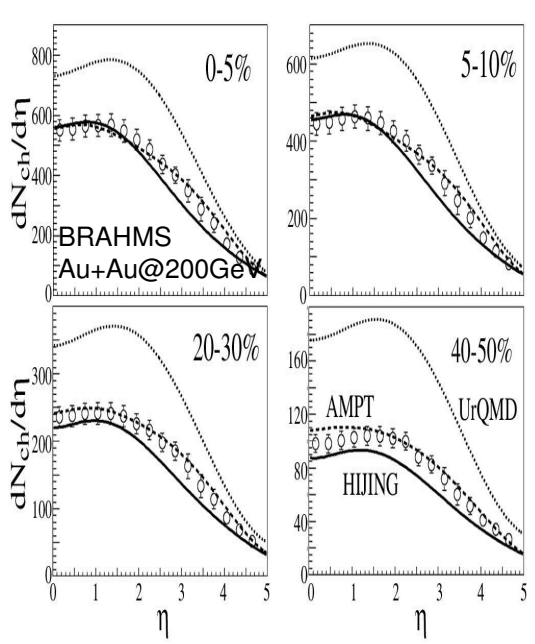
Default: Lin, Pal, Zhang, Li &Ko, PRC 61, 067901 (00); 64, 041901 (01); 72, 064901 (05); http://www-cunuke.phys.columbia.edu/OSCAR

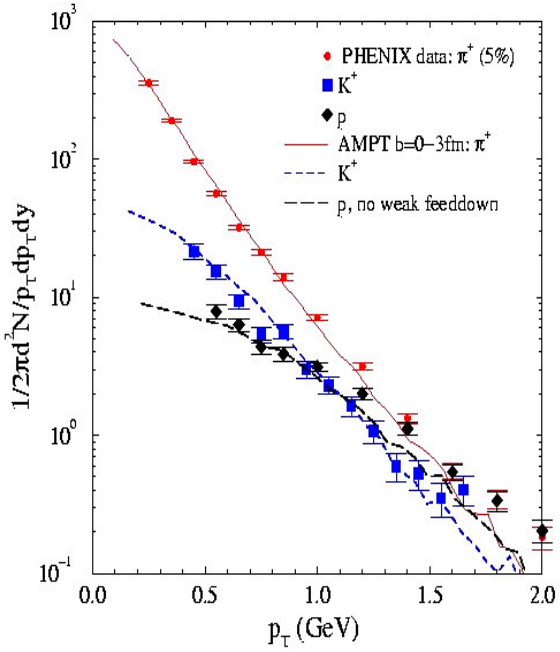
- Initial conditions: HIJING (soft strings and hard minijets)
- Parton evolution: ZPC
- Hadronization: Lund string model for default AMPT
- Hadronic scattering: ART

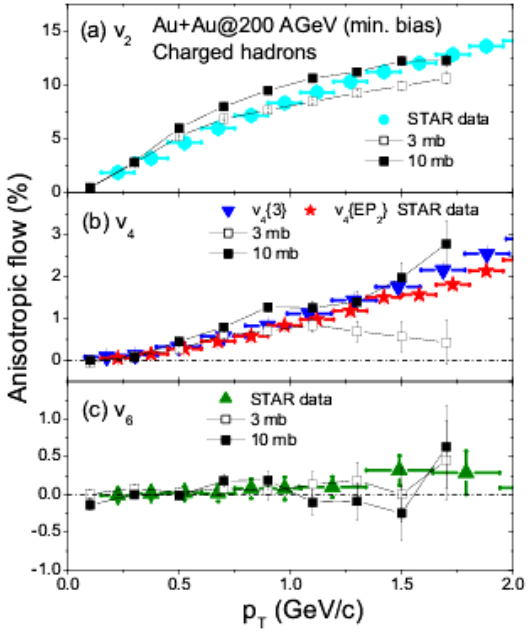
String melting: PRC 65, 034904 (02); PRL 89, 152301 (02)

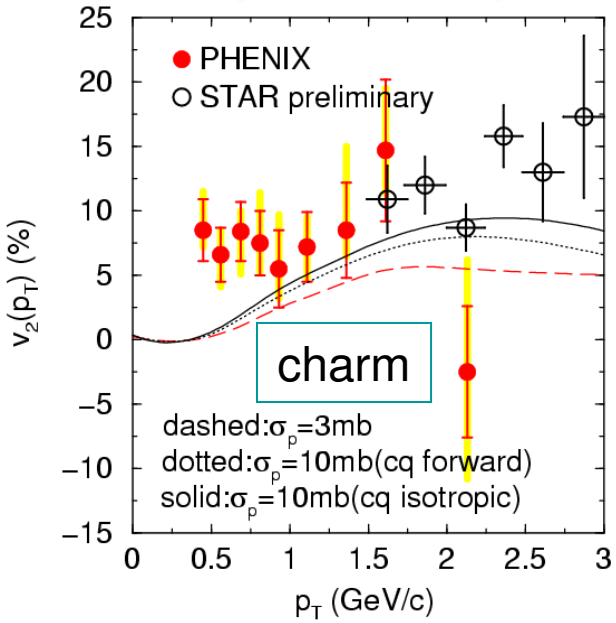
- Convert hadrons from string fragmentation into quarks and antiquarks
- Evolve quarks and antiquarks in ZPC
- When partons stop interacting, combine nearest quark and antiquark to meson, and nearest three quarks to baryon (coordinate-space coalescence)
- Hadron flavors are determined by quarks' invariant mass

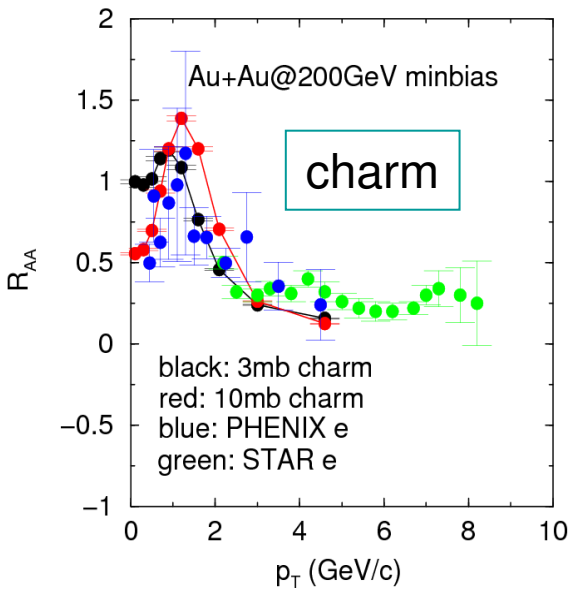
Results from AMPT for RHIC

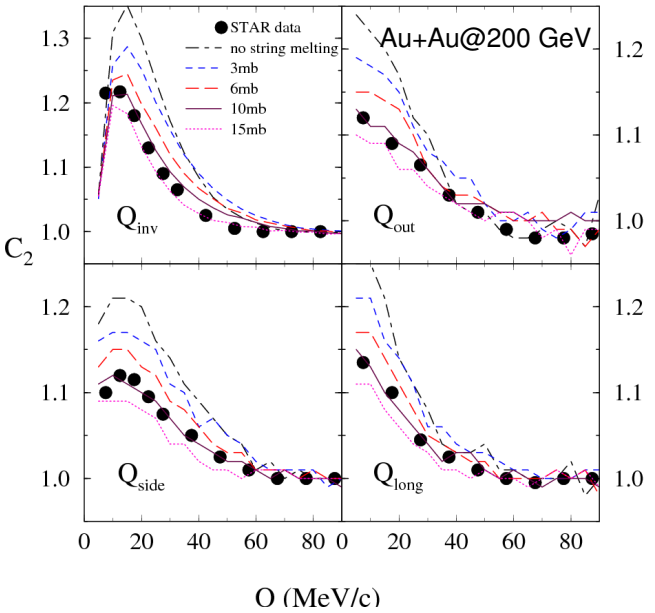






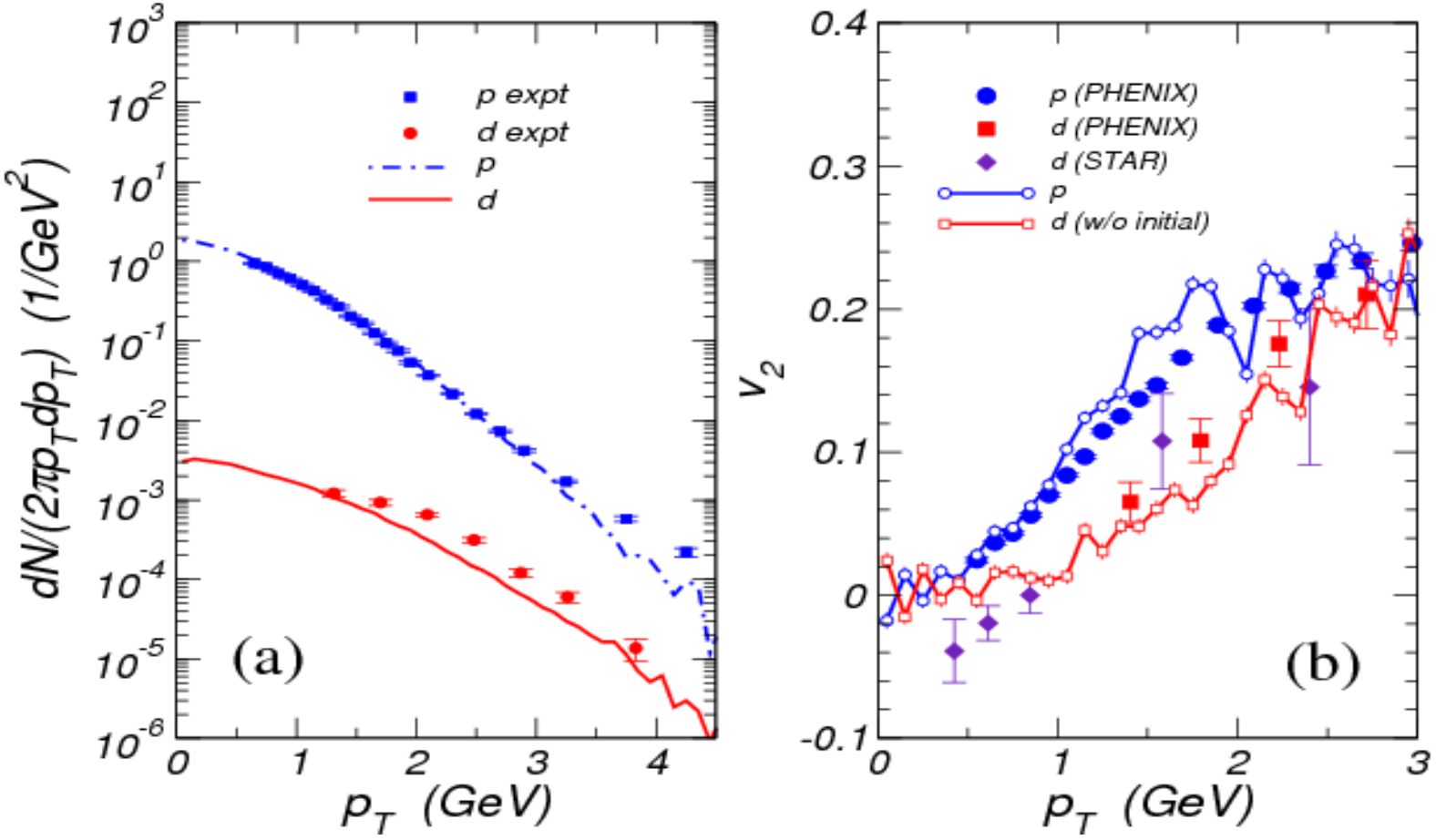






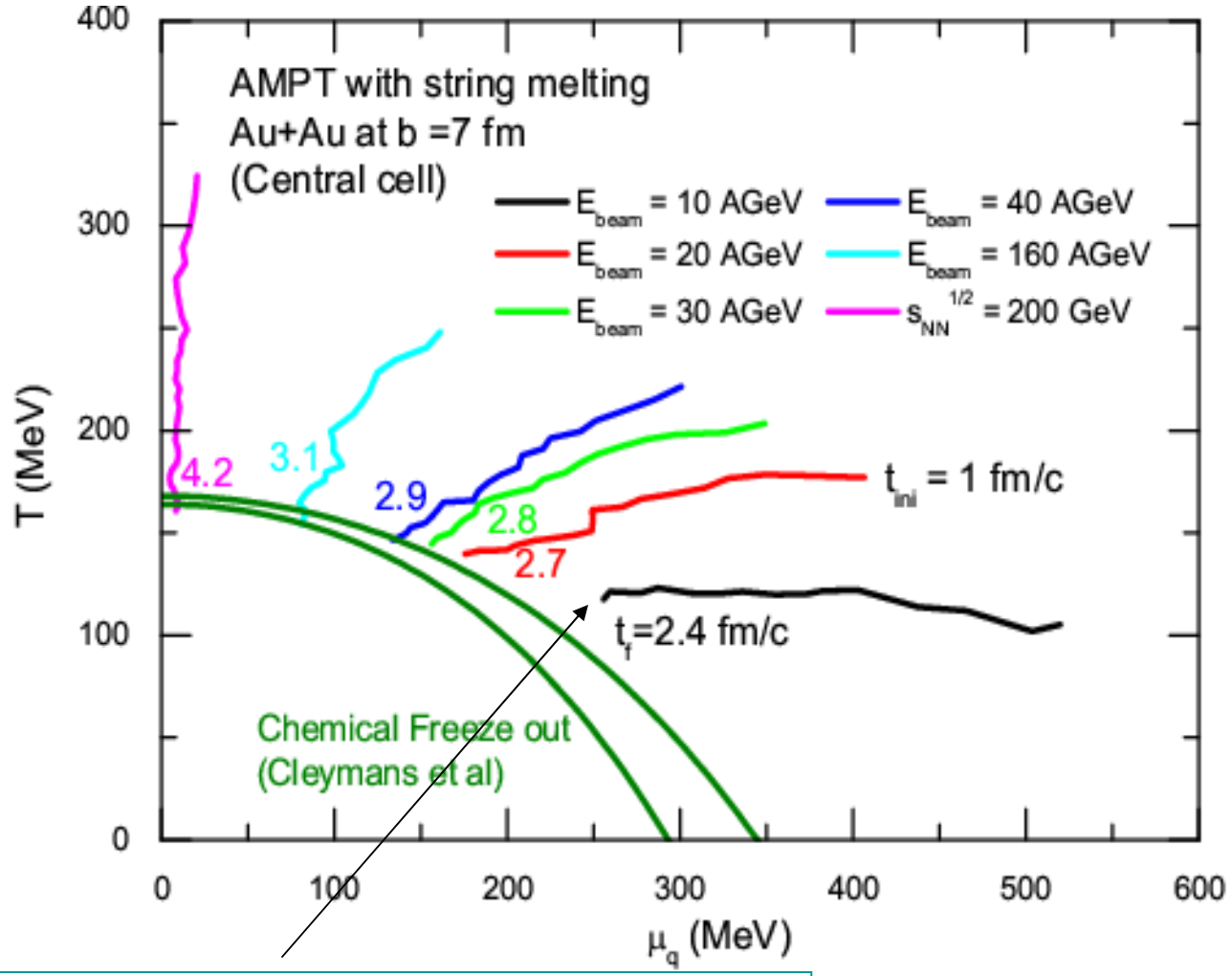
Recent updates on AMPT

- Inclusion of deuteron production via NN→dπ (Lin & Oh)



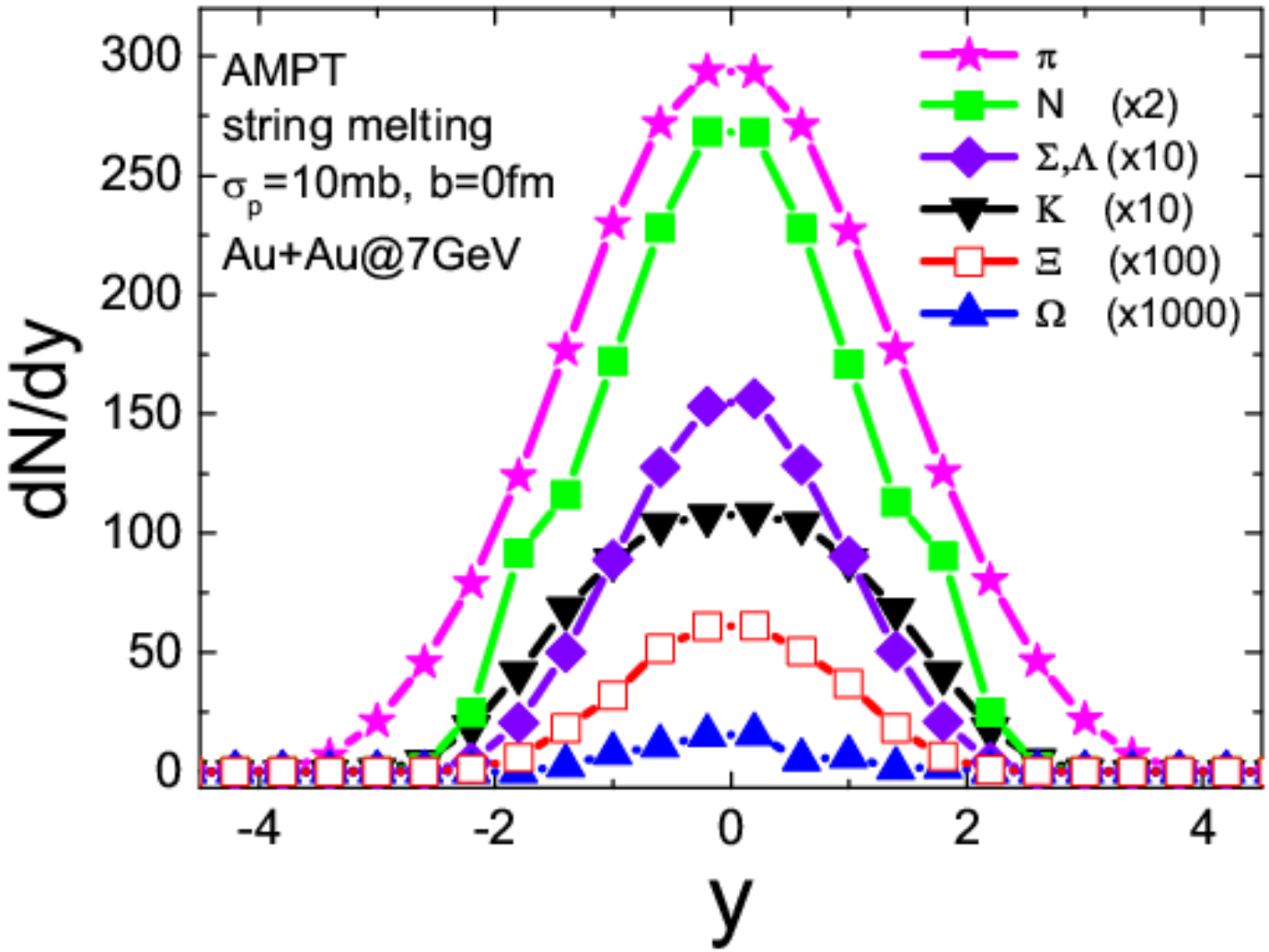
- Inclusion of radiative transport (2→3) in ZPC (Zhang)

Mapping the phase diagram via heavy ion collisions

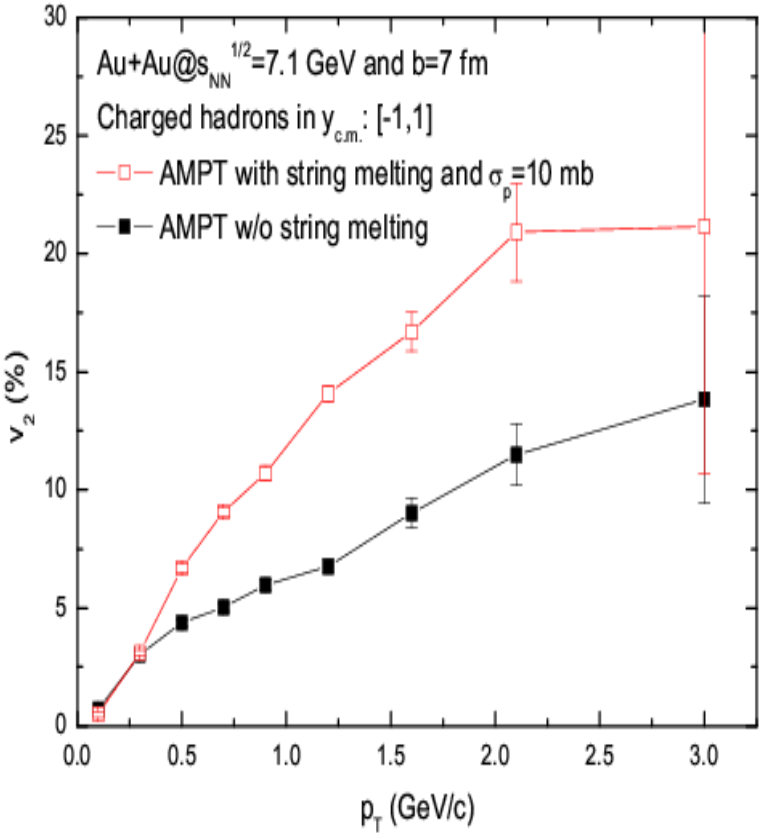


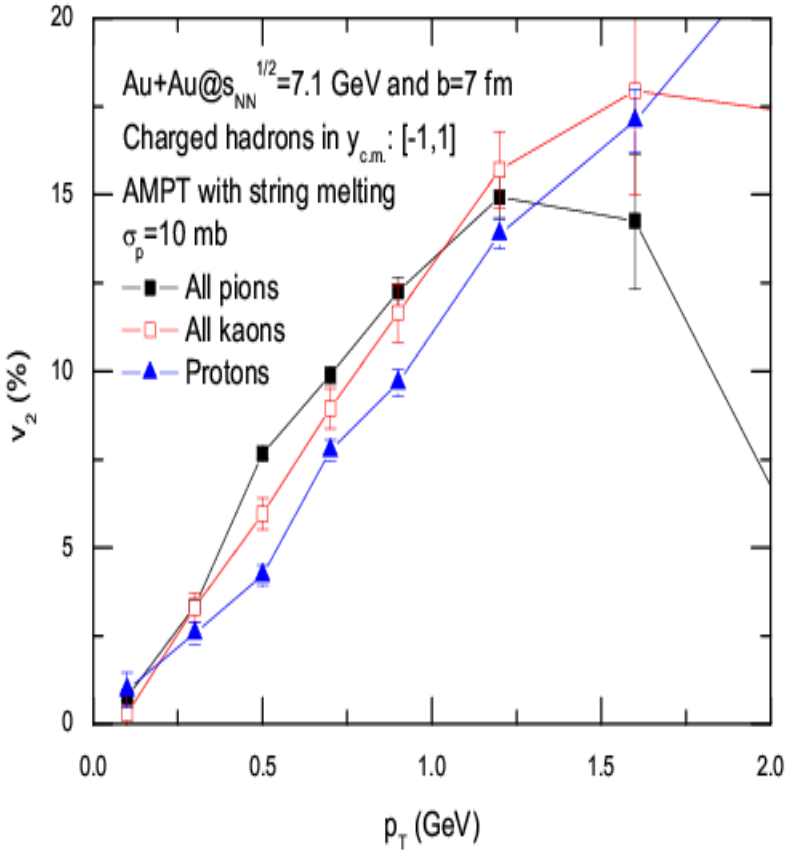
Require first-order phase transition ?

Rapidity distributions



Elliptic flow

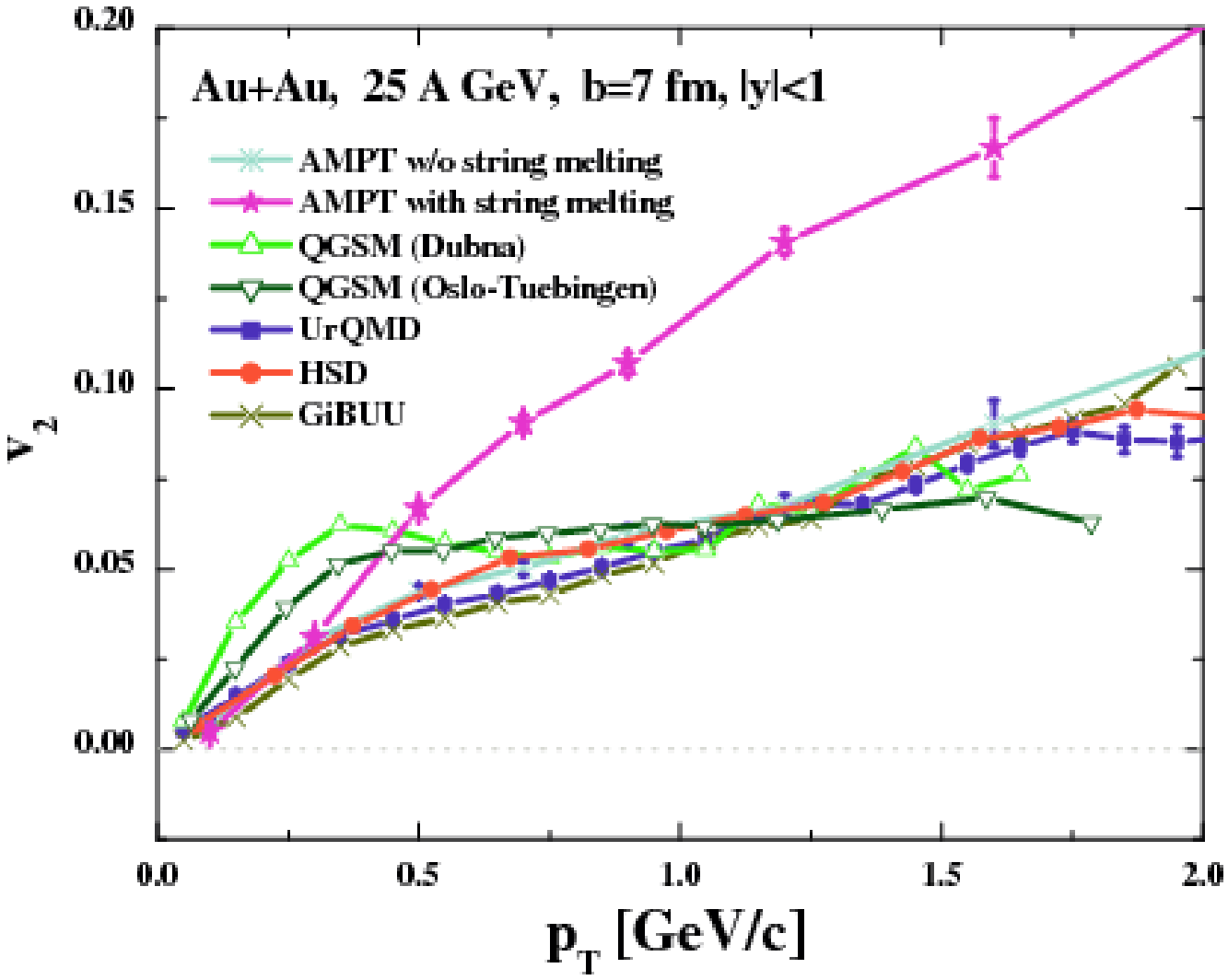




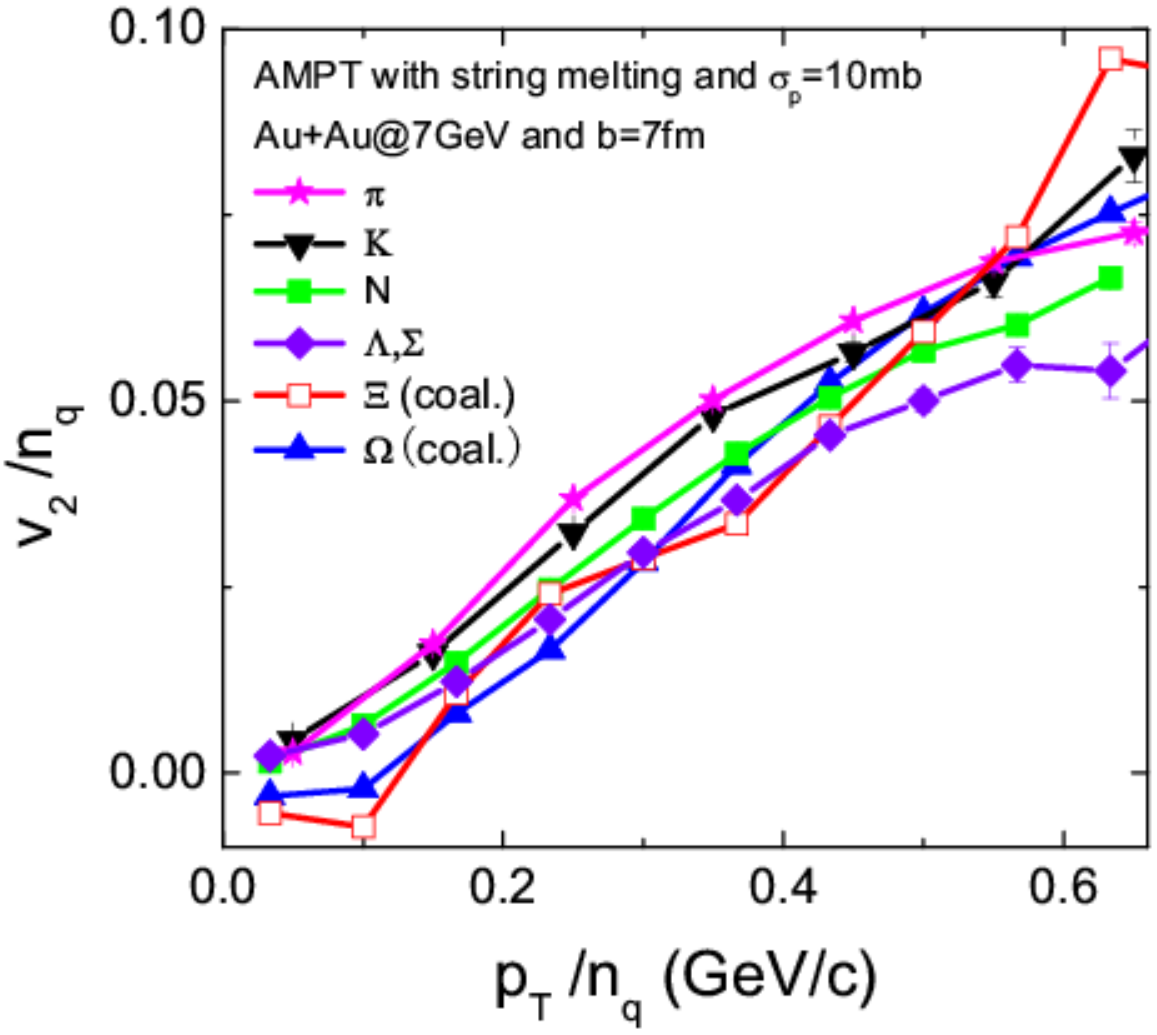
Partonic scattering enhances elliptic flow

Mass ordering of hadron elliptic flows

Comparison of transport model predictions of elliptic flow

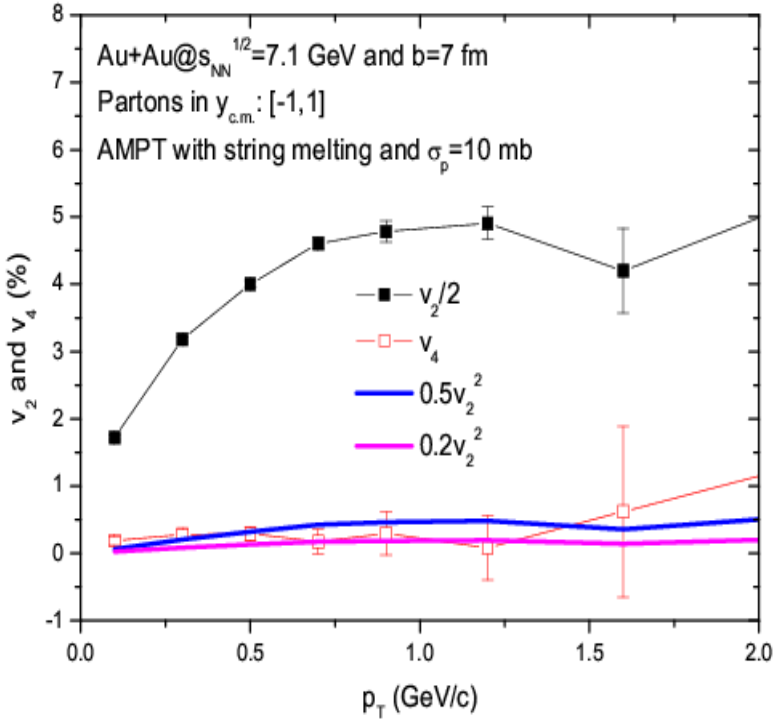


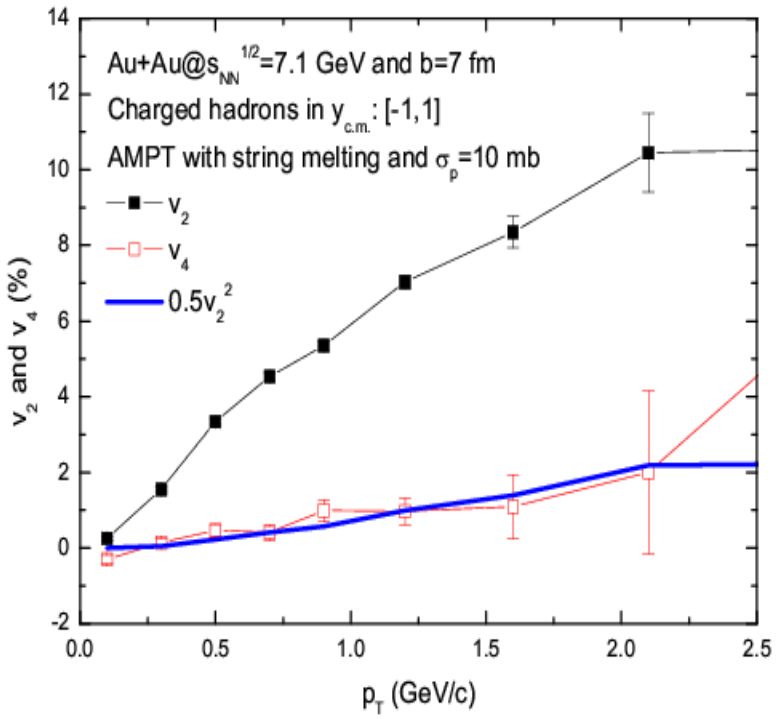
Scaled hadron elliptic flows



Approximate constituent quark number scaling !

Hexadecupole flow

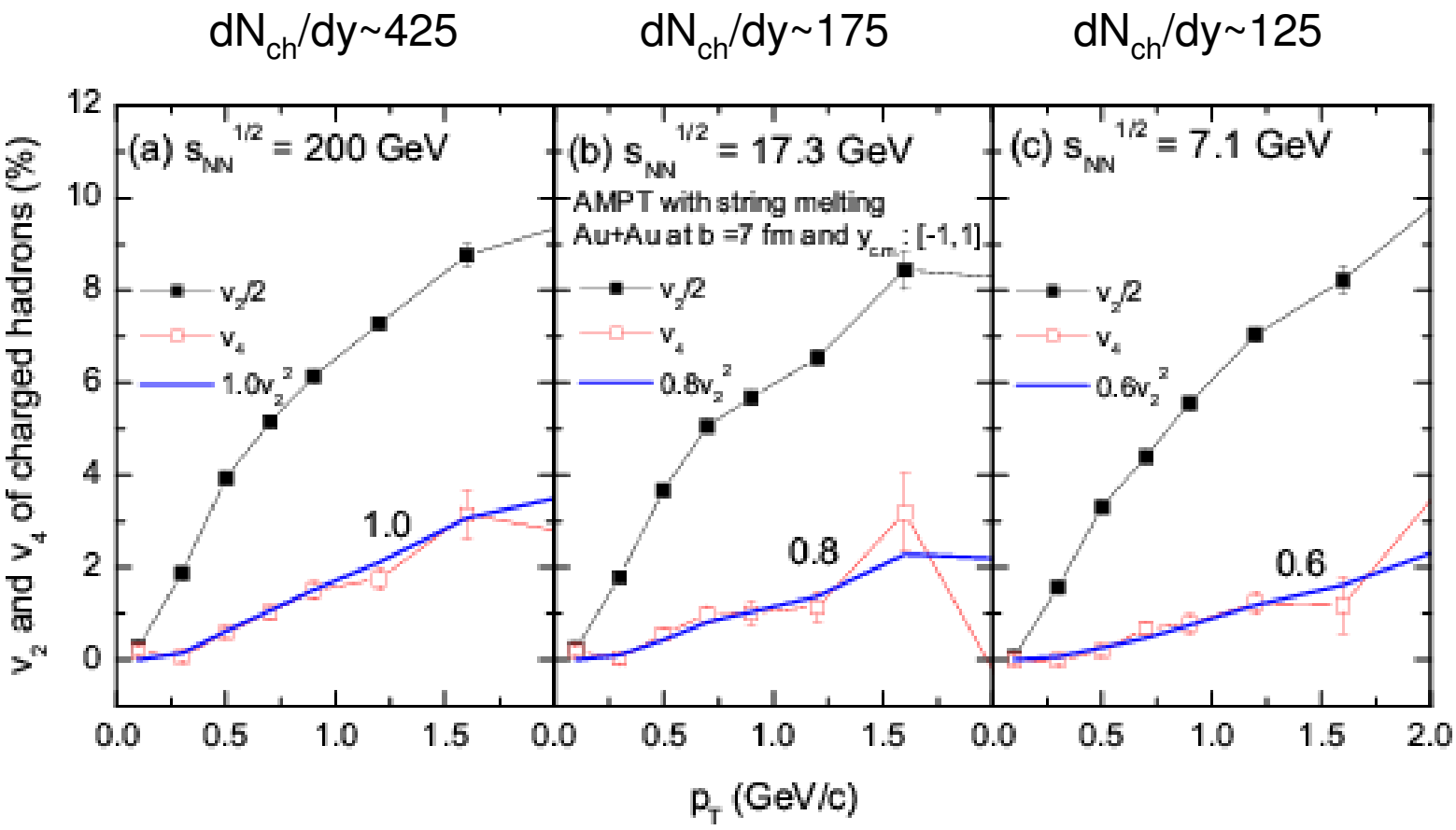




v_4/v_2^2 ~ 0.2-0.5 for partons and ~0.5 for charged hadrons, consistent with momentum-space coalescence

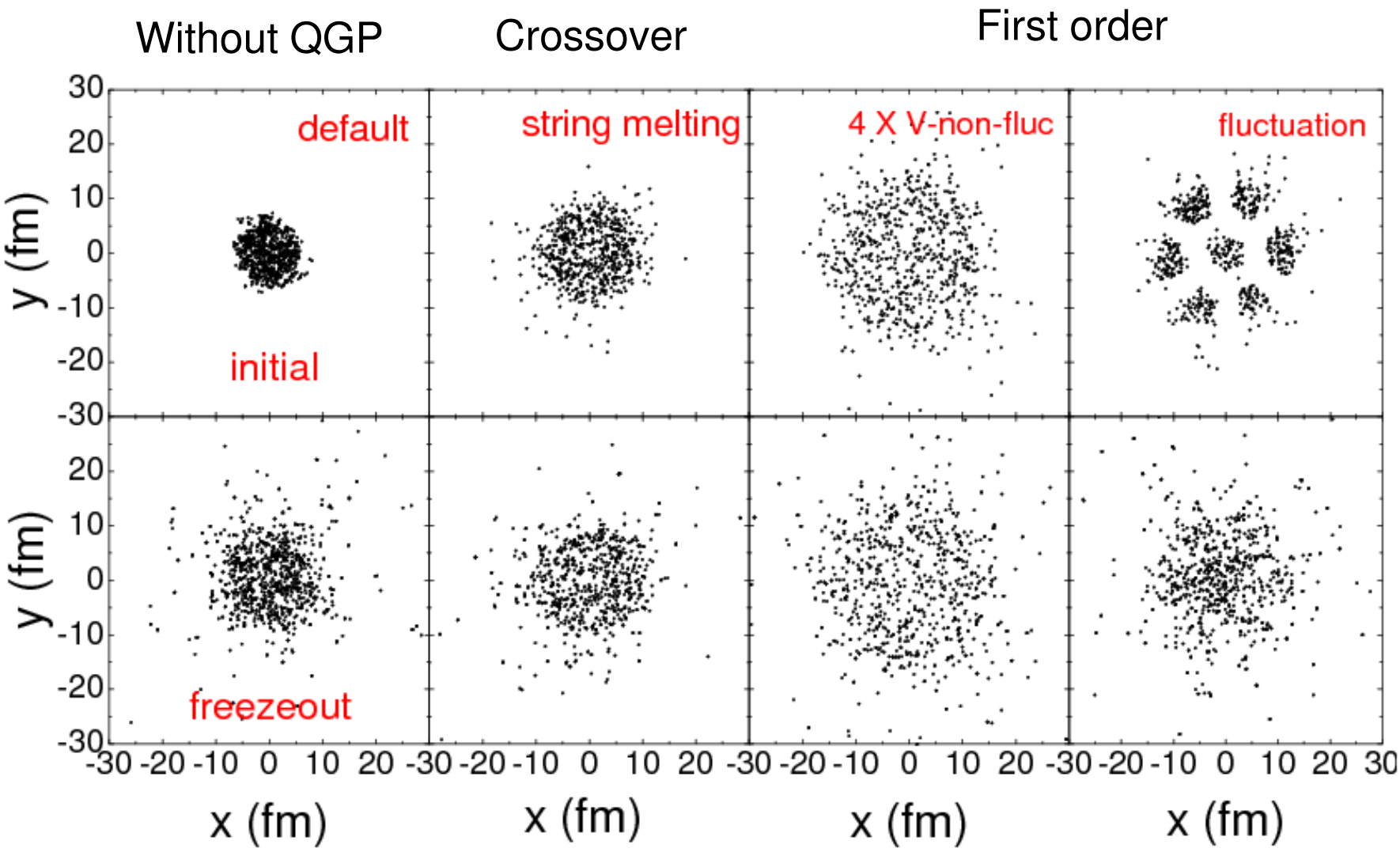
$$\frac{v_{4,M}}{v_{2,M}^2} = \frac{1}{4} + \frac{1}{2}\frac{v_{4,q}}{v_{2,q}^2}, \qquad \frac{v_{4,B}}{v_{2,B}^2} = \frac{1}{3} + \frac{1}{3}\frac{v_{4,q}}{v_{2,q}^2}$$

Energy dependence of v_2 and v_4



- Magnitude of v_2 essentially independent of collision energy
- v_4/v_2^2 increases with collision energy

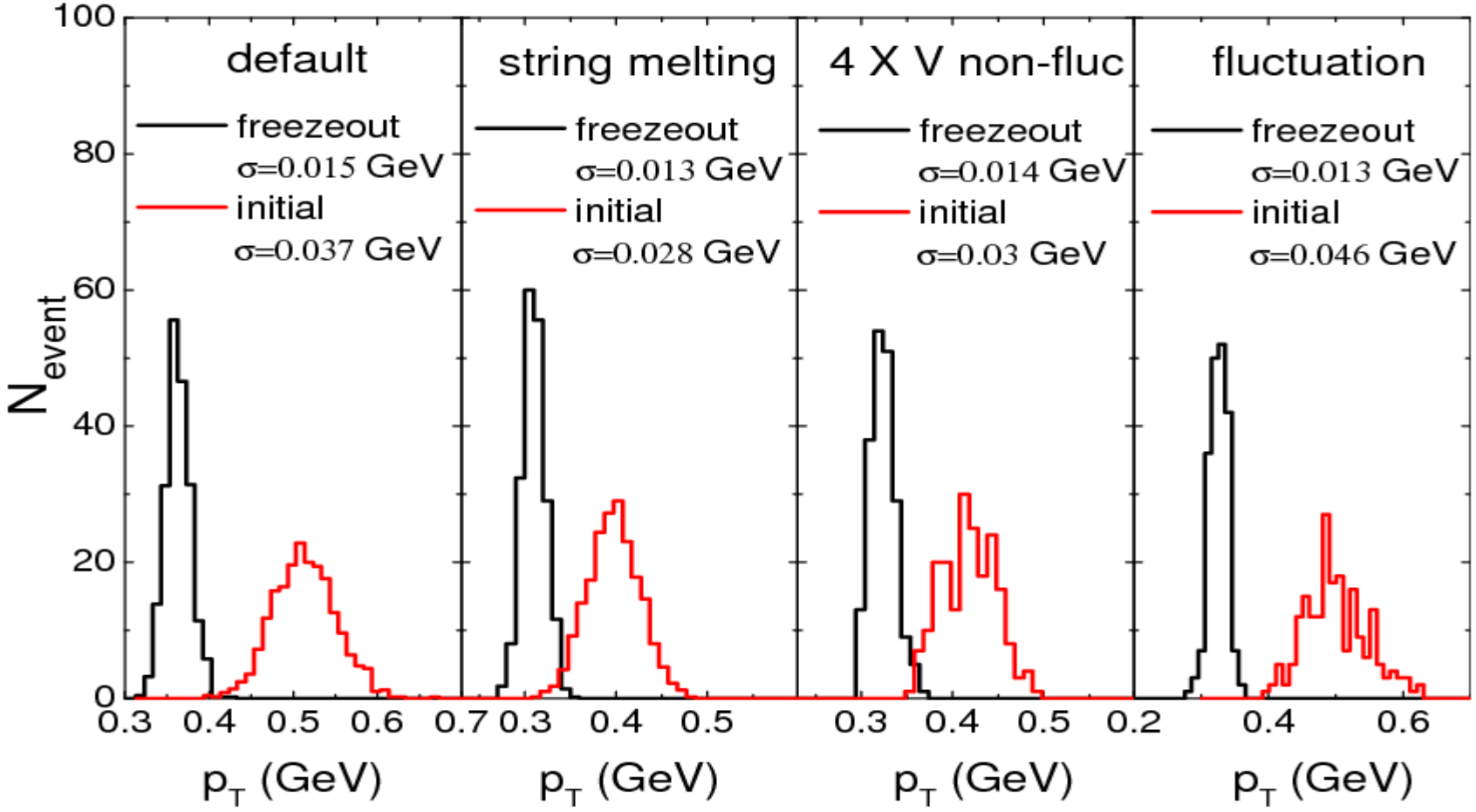
Phase transition and effect of hadronic scattering



First-order phase transition modeled by increasing initial volume of hadronic matter by 4 and with or without density fluctuation

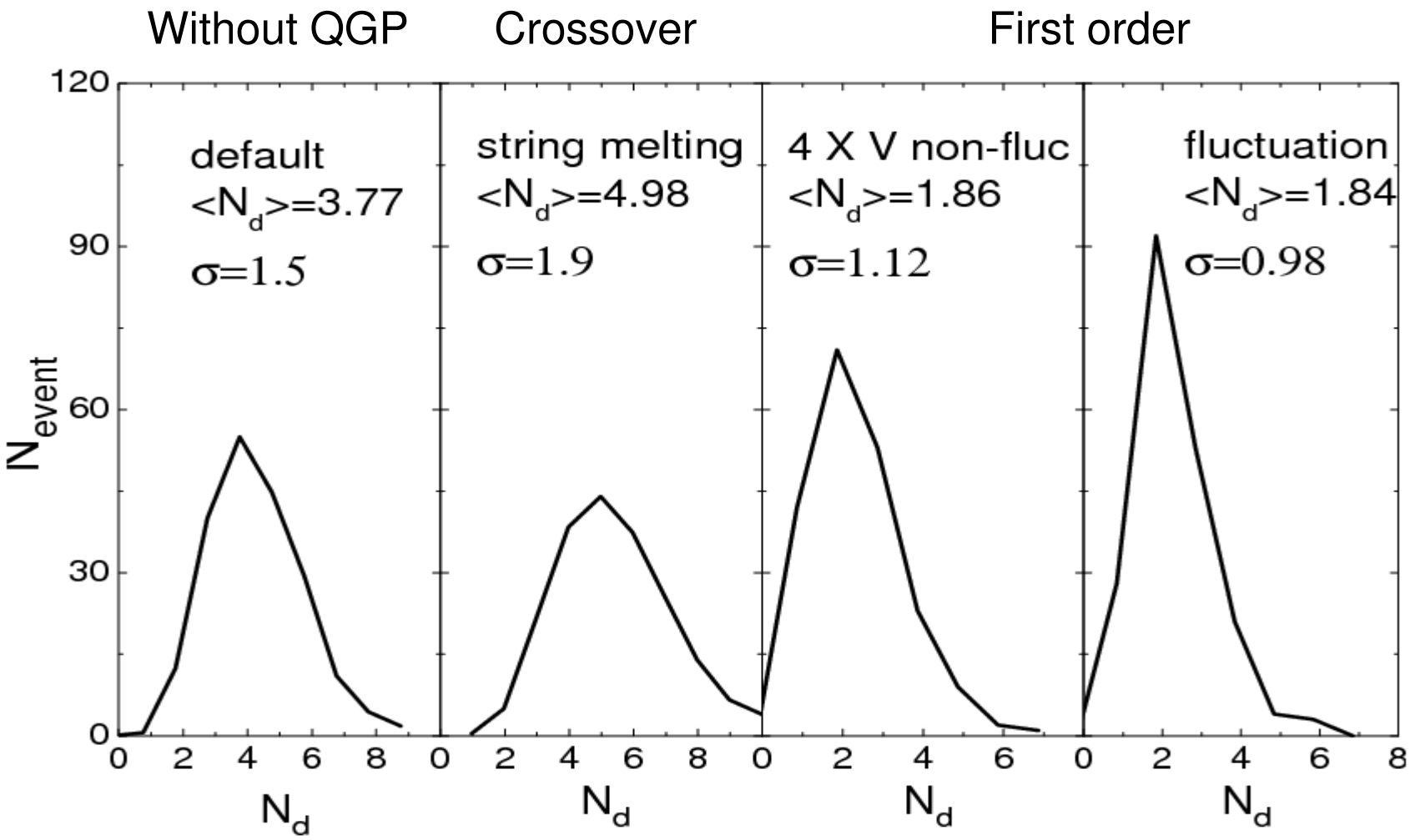
Mean transverse momentum fluctuation

Without QGP Crossover First order



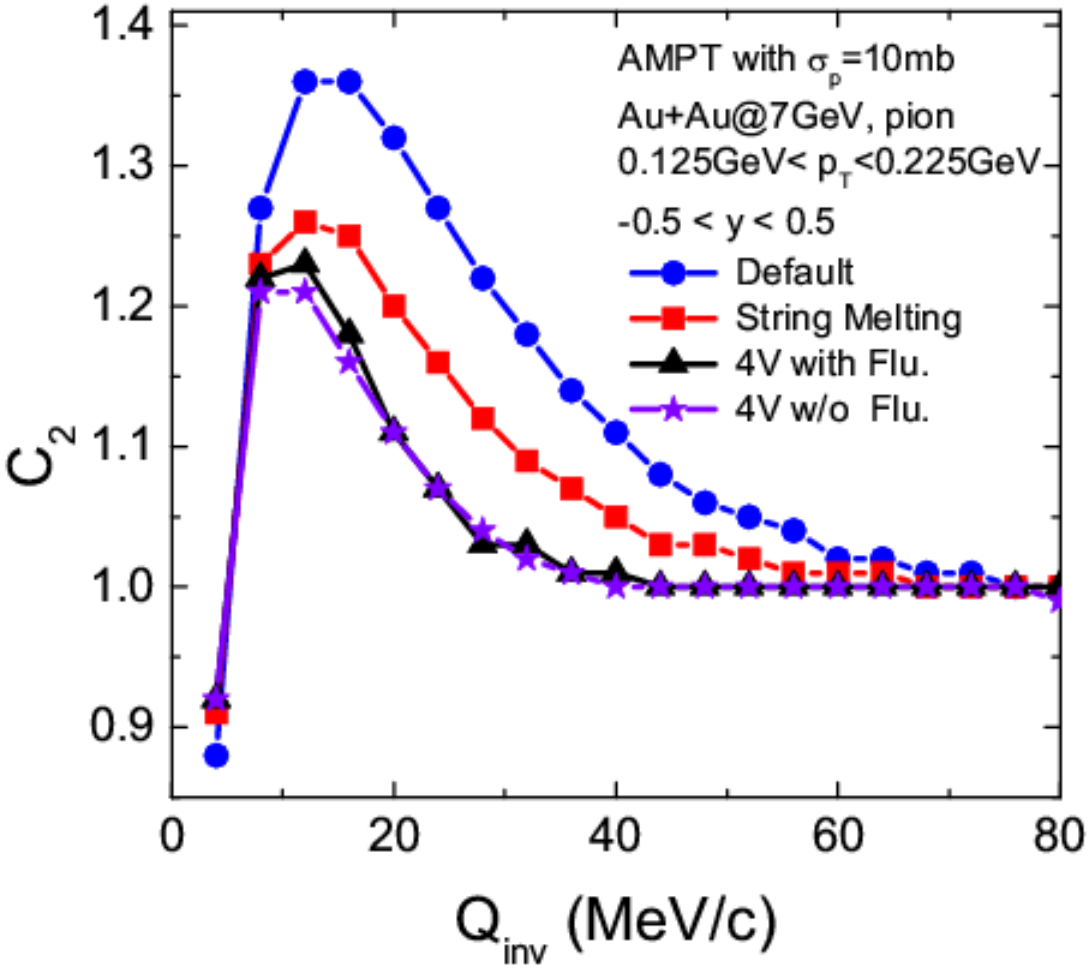
Similar mean transverse momentum fluctuation after hadronic scattering

Deuteron yield



Deuteron yield is reduced if there is a first-order phase transition but is not affected by initial density fluctuation

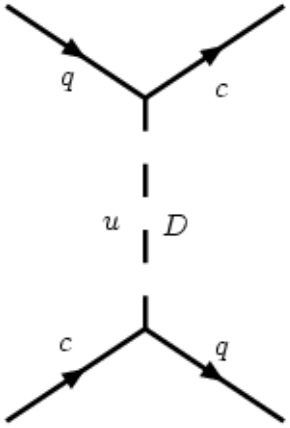
Two-pion correlation functions



First-order phase transition leads to a narrow correlation function but effect of density fluctuation is not seen

Resonance effect on charm scattering in QGP

Van Hees & Rapp, PRC 71, 034907 (2005)



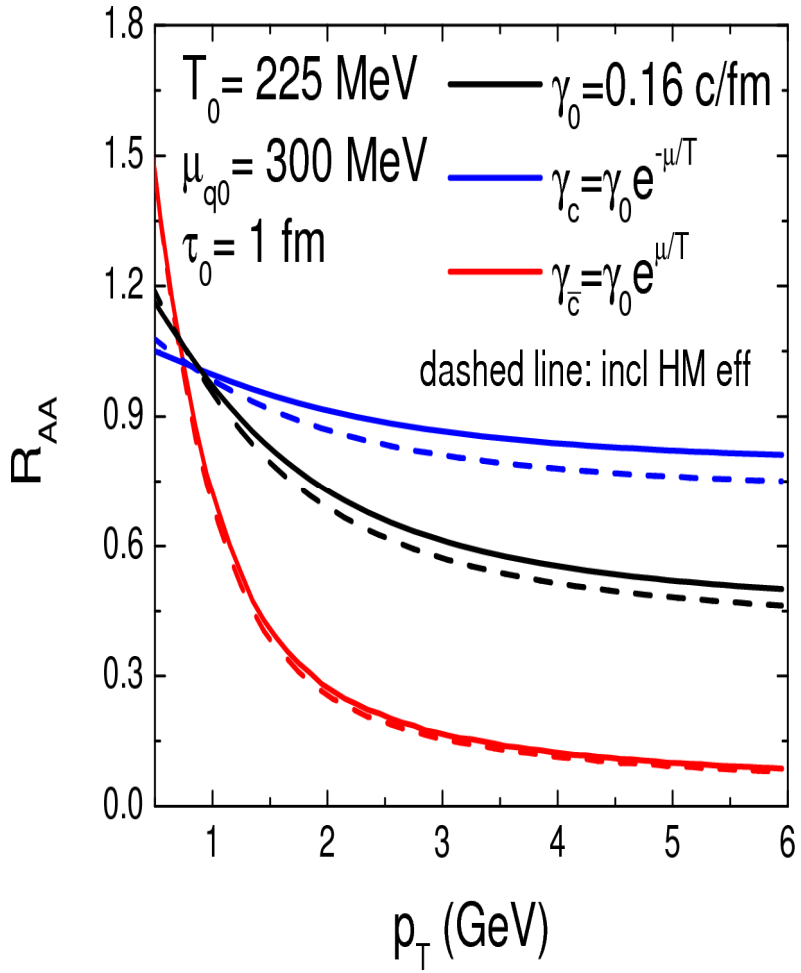
$$\sigma_{c\bar{q}\to c\bar{q}} = \frac{1}{9}\frac{2J+1}{4}\frac{\pi}{k^2}\frac{\Gamma_D^2}{\left(s^{1/2}-m_D\right)^2+\Gamma_D^2/4}$$

With $m_c \approx 1.5$ GeV, $m_q \approx 5$-10 MeV, $m_D \approx 2$ GeV, $\Gamma_D \approx 0.3$-0.5 GeV, and including scalar, pseudoscalar, vector, and axial vector D mesons gives

$$\sigma_{cq\to cq}(s^{1/2}=m_D) \approx 6 \text{ mb}$$

Since the cross section is isotropic, the transport cross section is 6 mb, which is about 4 times larger than that due to pQCD t-channel diagrams, leading to a charm quark drag coefficient γ ~ 0.16 c/fm in QGP at T=225 MeV.

Charm suppression in baryon-rich QGP

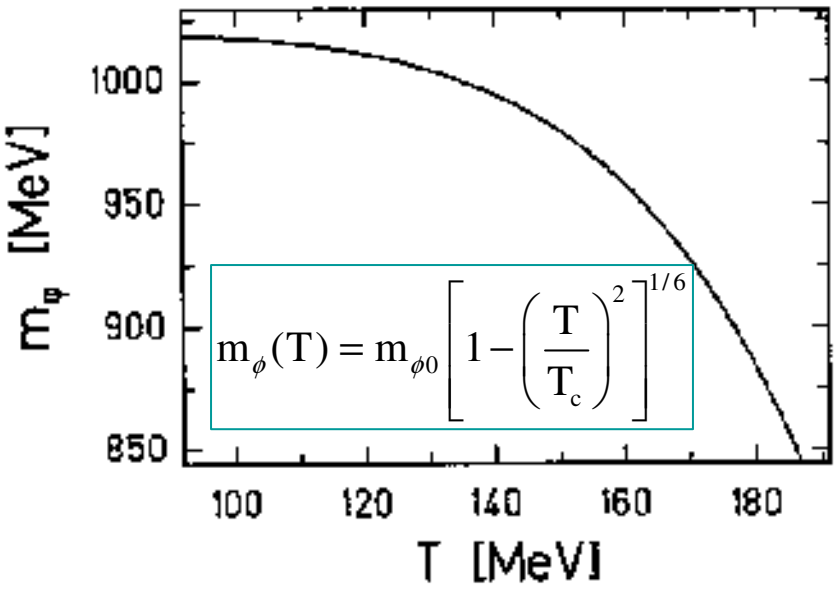


$$R_{AA} = \frac{dN_{Au+Au}}{\langle T_{AA} \rangle d\sigma_{p+p}}$$

- dN_{Au+Au}= differential heavy flavor yield in Au+Au collisions
- $d\sigma_{p+p}$= corresponding differential cross section in p+p collisions
- $\langle T_{AA} \rangle$= nuclear overlap integral

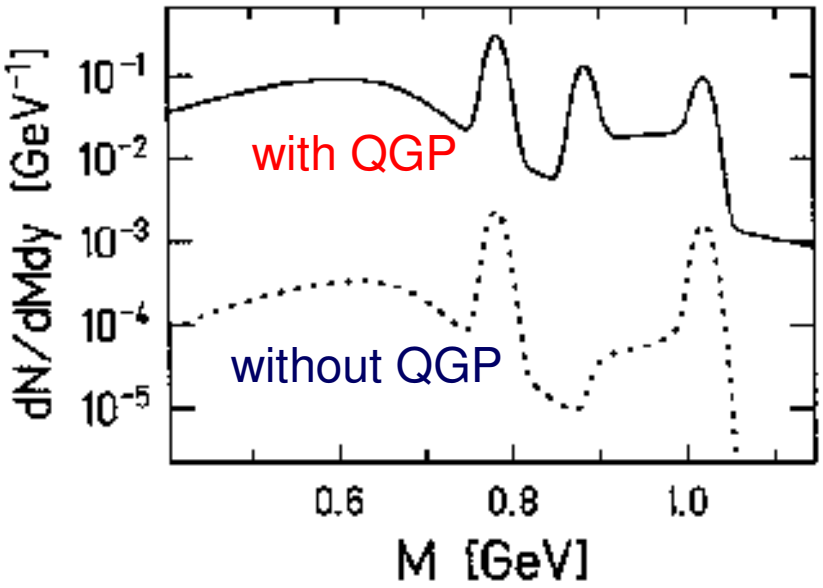
- pQCD gives similar c and cbar cross sections in QGP, irrespective to the baryon chemical potential (solid line).
- Resonance scattering leads to different c and cbar cross sections in QGP with finite baryon chemical potential (solid and dashed lines)

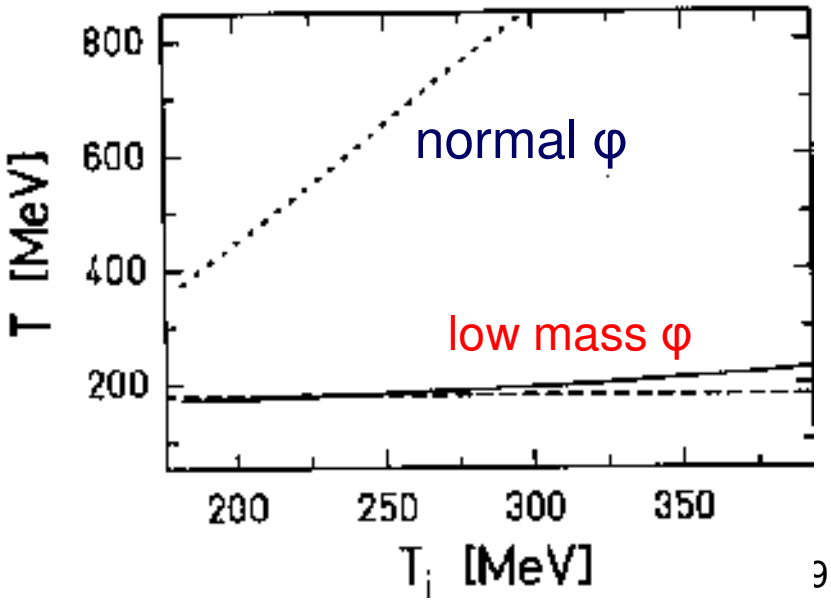
QGP phase transition and Double phi peaks



Asakawa & Ko, PLB 322, 33 (1994); PRC 50, 3046 (1994)

Boost-invariant hydro with transverse flow: T_0=250 MeV; T_c=180 MeV, T_f=120 MeV





Summary

- Elliptic flow is appreciable if a partonic matter is formed.
- Approximate constituent quark number scaling of hadron elliptic flows is expected.
- v_4/v_2^2 is smaller in HIC at lower energy than at SPS and RHIC.
- First-order phase transition affects deuteron yield and two-particle correlation functions, but effect of density fluctuation is likely washed out by hadronic scattering.
- Comparison of charm and anticharm losses in baryon-rich QGP could distinguish the mechanism for their energy loss.
- First-order phase transition may lead to double phi peaks in dilepton spectrum.